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**Pest Management Grants Progress Report**

**Contract: 00- 0194S**

**AERIAL RELEASE OF *TRICHOGRAMMA* TO CONTROL CODLING MOTH**

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## **ACKNOWLEDGMENTS**

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## ABSTRACT

Work by the principal investigator during the 1998-2000 growing seasons demonstrated the technical success of metering and applying *Trichogramma* parasitized *Ephestia* eggs, in conjunction with an adhesive, from an aircraft to adhere *Trichogramma* parasitoids to the foliage of walnut trees. *Trichogramma* also have been demonstrated to provide control of codling moth damage in walnuts, particularly when used in conjunction with mating disruption protocols..

This project has provided aerial release of *Trichogramma* parasitoids for an additional year in conjunction with the Walnut Pest Management Alliance (PMA) Work Plan, whose personnel provided monitoring, timing, and designed the various strategies described below. The principal investigator provided the pheromones for the first and second generations plus *Trichogramma* parasitoids for third generation (four) releases, reducing costs to growers.

The goal of the PMA Work Plan is to demonstrate and implement reduced-risk pest management systems in walnuts statewide and to communicate these strategies to the walnut industry. The use of *Trichogramma* to control codling moth is one component of these strategies. During the 2001 season, test plots were managed with several strategies including: mating disruption and conventional pesticides, mating disruption and *Trichogramma*, mating disruption alone, conventional pesticides alone, and control plots where no pest control was implemented. The use of pheromones for mating disruption has appeared promising, but is more expensive overall. Ground-based application of pheromone dispensers is laborious. A ground-sprayable version of pheromones was implemented this year, but the multiple applications required also were expensive. A single test plot utilizing an aerial method for pheromone application (stand-alone without *Trichogramma*) was conducted this growing season and results were very good, considering the specific circumstances, and costs are encouraging.

The goal of this proposal was to provide an additional year of aerial releases of *Trichogramma* and pheromones to control codling moth. Some of the Walnut PMA sites used in 2000 were used again during the 2001 season. The test plots used during the 2001 season were the same size as those used in 2000.

Demonstrating an additional year of success of a reduced-risk pest management strategy has improved the likelihood of adoption by the walnut industry.

## EXECUTIVE SUMMARY

*Cydia pomonella*, codling moth, is a serious exotic pest in walnuts and other crops in California. California produces virtually all the commercial walnuts in the United States on over 200,000 acres in 20 counties, with an annual crop value of over \$280 million. The Food Quality Protection Act will eliminate or reduce the use of commercial products such as Guthion and similar organophosphates that currently control codling moth populations. Therefore, alternative strategies, such as the use of *Trichogramma*, must be developed. Two major challenges to the implementation of *Trichogramma* in walnuts have been 1) how to place the parasitized eggs in the orchard canopy where the codling moths are found, and 2) how to do so economically. Previous work, supported by USDA Small Business Innovation & Research (SBIR) funds, has demonstrated the technical feasibility of metering and applying *Trichogramma* parasitized *Ephestia* eggs (parasitoids) from an aircraft, in conjunction with an adhesive, to adhere *Trichogramma* parasitoids to the foliage of walnut trees. *Trichogramma* also have been demonstrated to provide a measure of control of codling moth in walnuts, and that control may be improved when combined with other Integrated Pest Management (IPM) strategies, such as pheromone-based mating disruption. This project has provided the aerial release of *Trichogramma* parasitoids and aerial pheromone application demonstrations, under controlled and monitored conditions, in conjunction with the Pest Management Alliance (PMA) Work Plan for California Walnuts, to answer these questions.

In cooperation with the Walnut PMA, 4 timed releases of *Trichogramma* parasitoids were made over 16.5 acres of walnuts located in four orchards and involving growers in four counties. An additional 5.4 acre plot received a 1-time, novel aerial application of pheromones. The strategies used during the 2001 season for codling moth control were: 1) mating disruption alone (using Isomate) - at 2 different rates/acre, 2) mating disruption (Isomate) and Confirm/Lorsban, 3) mating disruption (Isomate) and *Trichogramma*, 4) Confirm/Lorsban alone, 5) sprayable (ground) pheromone alone, 6) sprayable (ground) pheromone and Confirm/Lorsban, 7) aerial Isomate, and 8) grower standard, all of which were compared to control plots where no codling moth control measures were implemented.

Monitoring of the codling moth population is an important component in the success of these reduced-risk strategies. Without accurate monitoring, implementation of the reduced-risk strategy can be ill-timed and subsequent control rates are inadequate for the method to be acceptable on a commercial scale. The Walnut PMA was responsible for the monitoring protocols throughout the season and determined the pheromone and/or *Trichogramma* release dates. A second component of these reduced risk strategies is the ability to apply the strategy once monitoring has determined the optimum timing of the method. For a third year, there were no problems with the *Trichogramma* release system, which provides rapid and accurate (both in location and rate) releases of the parasitoids onto the walnut canopy. The success of the aerial application of pheromones this season has been particularly exciting.

For these reduced-risk strategies to be adopted commercially, they must be affordable. Monitoring is costly and reduced-risk strategies presently are more costly per

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acre than conventional pesticides. In this third year of trials, the cost of reduced-risk practices has been lowered by reducing the number of *Trichogramma* releases. The use of mating disruption during the first and second generations, followed by four releases of *Trichogramma* parasitoids in the third generation appears to have provided good control results, although final data are still pending.

Finally, together with the Walnut PMA, the principal investigator has demonstrated the aerial release of *Trichogramma* to be an effective component of reduced-risk strategies to control codling moth in walnuts. The results of these investigations have been disseminated to the walnut industry through various publications and meetings where the results of the program were well received.

## REPORT

### 1. INTRODUCTION -- Identification and Significance of the Problem

Codling moth, *Cydia pomonella*, is a major exotic pest of walnuts, apples and pears in California and elsewhere in the United States. It was introduced from Eurasia and has spread rapidly, becoming a major problem in three quarters of the California counties where walnuts are grown. There is a distinct race of codling moth with a preference for walnuts and a life cycle that is well synchronized with the development of early walnut cultivars such as Serr, Payne, Ashley and Chico. The nuts of these varieties mature early enough to support first generation larvae. Codling moths produce three generations per year and larval damage from the first generation is believed to be responsible for nut drop in June. Nut meat damage caused by third generation larvae is seen at harvest and is more easily quantified.

Control of codling moth is fundamental to the management of other insect pests in walnuts. Cultural or biological controls are not satisfactory on a commercial scale at this time. Current management depends on monitoring pest populations to determine optimum times to apply conventional pesticides. Present control methods vary from grower to grower. Some use organophosphates and carbamates alone, which involves two applications of Lorsban (chlorpyrifos) during the first generation in the spring followed by a single application of Guthion (azinphosmethyl) during each of the two subsequent insect generations. Other growers will alternate the use of organophosphates and carbamates in one year with the use of pyrethroids, such as Asana, in the following year. Unfortunately, the organophosphate and carbamate pesticides also eliminate the natural enemies of destructive aphids, mites and scale insects making additional chemical applications necessary to control these pests. The pyrethroid materials have been found to have long acting residual effects which negatively impact beneficial insects such as *Trichogramma*. Current practice results in over 300,000 lbs of active ingredient being applied annually in walnut orchards in California<sup>1</sup> at an estimated cost of \$150 per acre, excluding application and labor costs.

Guthion, the principal insecticide used against codling moth in the United States since the 1960's, has a long residual life and high mammalian toxicity.<sup>2</sup> Its effectiveness against codling moth has declined over the last few years, especially in the San Joaquin Valley, indicating the codling moth is developing resistance to this and potentially a range of other synthetic insecticides.<sup>3,4</sup> This reinforces the need for improved biological control methods.

California produces virtually all the commercially produced walnuts in the United States with over 205,000 acres in 20 counties dedicated to walnut production. Annual crop value is \$280 million, placing walnuts among the top five in California's fruit and nut crops.<sup>5,6,7</sup>

Conventional methods for the release of *Trichogramma* involve the refrigerated shipment of pupae, ready to emerge as adults, inside parasitized grain moth eggs (*Ephestia sp.* or *Sitotroga sp.*), known as parasitoids, which are glued to perforated cards (~100,000 parasitized eggs or a minimum of 50,000 females/card). The cards are broken



into ~2.5 cm squares (~15,000 females/square) on-site and distributed by hand in orchards by stapling the squares to leaves or by incubating the parasitized eggs in paper wedge cups, which are then set out after the adults emerge (2-5 days). Both the card and cup practices are highly labor intensive and slow and, therefore, prohibitively expensive on a commercial scale.

Pheromone-based mating disruption is one Integrated Pest Management (IPM) strategy for codling moth control<sup>8,9,10</sup> that has worked well in apples and pears. The pheromone dispensers that are so successful in apples and pears are placed in the orchards by hand. Unfortunately, pheromones as a stand-alone strategy have not been as successful in walnuts, particularly because there is no acceptable placement method that is fast and cost effective. This is due to the number of acres involved, and the much larger size of the trees (and subsequent large volume of air which must be permeated with pheromone). Pruning towers have been used to place pheromone dispensers in small test plots. They have proved to be slow (1-3 man-hours/acre @ \$8/hour), costly (~\$25/hour for the tower plus labor) and require a certain degree of skill/experience to operate safely. In addition, enough towers simply do not exist to apply this strategy on a commercial scale. Another pheromone application method that was tested involved the application of a sprayable pheromone using a ground-based sprayer. In limited test plots, this strategy proved to be costly and timing was constrained by ground-based issues, such as weather-related wet field conditions or timing around irrigation schedules.

At the close of the 1999 season, results were very encouraging showing that *Trichogramma* in conjunction with a soft pesticide (such as Confirm) provided an acceptable level of codling moth control. Work by the Walnut Pest Management Alliance (PMA) during the 2000 season has shown *Trichogramma* combined with mating disruption to provide an excellent potential for control. This is a safer approach, having virtually no impact on ground water or runoff, and no concerns from spray drift. The challenges, therefore, are to be able to apply these strategies to the larger acreages in a timely manner and for these strategies to be reasonably affordable to the walnut growers.

## **2. PROJECT OBJECTIVES**

- A. The specific objectives for this proposal were to provide aerial release of *Trichogramma* parasitoids as well as the aerial application of pheromones, to demonstrate the success of these systems and strategies at controlling codling moth in walnuts during a subsequent growing season.

The goal of the Walnut PMA Work Plan is to demonstrate and implement reduced-risk pest management programs in walnuts statewide and to communicate these strategies to the walnut industry. The use of *Trichogramma* to control codling moth is one of these strategies. Previous release protocols have been prohibitive because they were labor intensive and slow, and, therefore, both costly and less effective. The aerial release strategy is comparably priced and very fast, which has increased the potential for adoption of this method of control. This proposal provided the technical expertise to place the *Trichogramma* parasitized *Ephestia* eggs in the upper canopy of the walnut trees, where

the codling moths are present, in order to effect control of this significant pest without the use of conventional pesticides such as organophosphates. This proposal also provided an aerial application strategy for pheromones for mating disruption.

In cooperation with the Walnut PMA and based on the protocols described below (Table 1), the investigator made Four timed releases of *Trichogramma* parasitoids over 16.5 acres of walnuts located in four orchards belonging to growers in four counties (Table 2). By reducing the number of releases, cost per acre has been reduced significantly (see below). In addition, one plot (5.4 acres) was managed using aerially released pheromone dispensers, Table 3. This particular plot was located between test plots and an older orchard that was not part of the trials. The history of pest pressure in the adjoining orchard was not known and the buffer zone was to be "sprayed out" so the neighboring orchard would not influence. Using this buffer zone as a test plot for the aerial pheromone strategy would test the method and, if found that the aerial Isomate did not hold the pest population down, the buffer zone could be sprayed out to clean it up without influencing the other PMA plots.

Third generation canopy counts were not taken this year. Data was collected by the Walnut PMA team on nut damage only. All plots were monitored throughout the season using pheromone-baited traps. Trap counts appear promising and we expect results to support our previous work, demonstrating that *Trichogramma* parasitoids, in conjunction with pheromone-based mating disruption during the first and second generations, are a viable and potentially affordable reduced-risk pest management strategy. The combination of *Trichogramma* with pheromone-based mating disruption continues to appear to be a particularly promising strategy. We are also encouraged by the aerial Isomate "buffer" plot. Although the damage at harvest (3.2%) does not look particularly good at first, when one considers that the aerial Isomate strategy "held down" pest pressure from the neighboring orchard to below 5% without any previous treatments, that should be considered a good overall result. There also were some problems encountered with the application, but these were primarily mechanical and have been corrected with further development.

B. Communicate the success of this strategy to the industry

This objective also has been accomplished. This strategy has been communicated at four forums by the principal investigators and statewide by farm advisors and the members of the Walnut PMA.

### 3. RESULTS

A. Provide aerial release of *Trichogramma* parasitoids, in conjunction with an adhesive, to walnut orchards participating in the Walnut PMA .

Earlier work conducted by Nick Mills and Carolyn Pickel has demonstrated that *Trichogramma* do not perform adequately as a stand-alone method during the first generation, resulting in higher canopy counts in the second and third generations. Therefore, during the 2000 season "soft pesticides" such as Confirm were used during the

first generation followed by *Trichogramma* in the second and third generations. This strategy was successful, but fairly expensive (in both parasitoids and air time/labor) due to the number of releases made. In the 2001 season, the number of releases was reduced to determine if this lower-cost approach would provide adequate control, especially in conjunction with the use of the Isomate ties. It was found that if the ties are applied in April, they last to almost the end of the season. By releasing *Trichogramma* to coincide with the last generation, the thought was that the overlap would provide adequate codling moth control. This combination and overlap approach provided the best data and reduced the cost of the control strategy. The specific protocols that were implemented in the 2001 season were determined by Walnut PMA Task Force with oversight by Carolyn Pickel, Walnut PMA Field Team Coordinator, and are detailed in Table 1.

As described in the original proposal, appropriately timed aerial releases have been made. The timing of these releases was coordinated by Carolyn Pickel, based on data provided by the field monitoring scouts. Table 2 provides details of the release dates in each orchard. In the present growing season, releases were reduced from eight to four. By reducing the number of releases, we have reduced the cost by \$84 per acre, from \$298 to \$214, and control has been improved.

This additional year of releases has solidly reinforced the technical feasibility of placing the *Trichogramma* parasitoids in the canopy of the walnut orchards. It also has explored alternative and exciting protocols with pheromones, and further demonstrated the promising combination of pheromone-based mating disruption in the first and now the second generation, followed by *Trichogramma* in third generation.

As noted above, *Trichogramma* have not been sufficiently effective during the first generation and alternative control methods have been and will be required. Results to date indicate that pheromone-based mating disruption will be an appropriate partner for *Trichogramma*. The application of pheromones by air will reduce the high labor costs associated with pheromone ties, which, when combined with the release of fewer parasitoids, will further reduce costs to the grower for this alternative pest management strategy.

Pest monitoring data graphs, provided by the University of California Statewide Integrated Pest Management Project, are available on the UC Davis IPM website: <http://www.ipm.ucdavis.edu>. These graphs illustrate the fluctuations in codling moth population during the season, by county, and allow comparisons of various treatment strategies. The FACT SHEET on Mating Disruption in Walnuts to Control Codling Moth, prepared by Carolyn Pickel for the Walnut PMA Meeting, November 2001, summarized this data and presented the following results (Table 4, used with permission):

It is with particular pleasure that we point out that the Isomate + *Trichogramma* protocol (highlighted) provided the best average in the four counties where the protocol was employed.

**B. Communicate the success of this strategy to the industry**

This goal has been met. The beneficial insect release system has been presented by the principal investigator at the Community Alliance with Family Farmers Field Day, March 23, 2001, and at the Walnut Pest Management Alliance Meeting, April 5, 2001 at the Glide Ranch, Davis, CA. It also was presented at the Partnerships for Sustaining California Agriculture: Profit, Environmental and Community, March 27-28, 2001 in Woodland, CA, the Walnut Growers Field Day, Chappe Farms, Farming, CA, September 10, 2001, and the PMS Field Day, Deseret Farms, Chico, CA, November 9, 2001. In all circumstances, the program was well received. In addition to these personal presentations by the principal investigator, this strategy has been communicated statewide by farm advisors and the members of the Walnut PMA. Finally, new approaches to combating codling moth was the cover story for the February 2002 issue of California Farmer, including a paragraph on the aerial pheromone strategy employed this past season.

**4. DISCUSSION**

In order for this reduced risk pest control strategy to gain acceptance with growers, it must be cost effective. For each of the test plots, the reduced risk treatment costs were the same and, for comparison, the total costs (labor, materials and equipment) for the treatments are provided in Table 5, below. Data were provided by the Walnut PMA.

It is important to note that costs per acre have been reduced as research has progressed in the use of *Trichogramma* as a component in alternative pest control strategies. We expect similar reductions in the cost of pheromone-based components as the use of pheromones is "fine tuned" to optimize the amount of active ingredient per acre required in each particular situation. Similarly, it is anticipated that the cost of these alternative strategies will change, hopefully lower, as the products become more widely accepted and utilized.

**5. SUMMARY AND CONCLUSIONS**

The timetable for this project has been met and the expenses are well within the budget proposed. There have been no significant problems and the principal investigator has not been prevented from meeting the objectives of the proposal or completing any of the specified tasks.

This project is demonstrating several combinations of successful alternatives to highly toxic pesticides, which reduces use of and human exposure to those pesticides while protecting surface and ground water quality. In addition, this project is a cooperative and collaborative effort between growers, the Walnut PMA, and industry that uses a systems approach to the solution of a significant problem in the walnut industry.

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## APPENDIX

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**TABLE 1 - Test Plot Protocols for 2001**

Isomate - 400	Pheromone-permeated dispensers applied (by hand) at a rate of 400 "ties" per acre.
Isomate - 200	Pheromone-permeated dispensers applied (by hand) at a rate of 200 "ties" per acre.
Isomate - Aerial	New strategy - The pheromone product was applied by air by the PI.
Isomate/ <i>Trichogramma</i>	One application of Isomate covers the first and second generations followed by <i>Trichogramma</i> in the third generation.
Isomate + Confirm/Lorsban	Isomate, in a dispensing apparatus, in the first generation, or until the dispensers are expended. Lorsban or Confirm is used in second and third generations.
Confirm/Lorsban	Lorsban or Confirm are used without any pheromone or <i>Trichogramma</i> .
Sprayable Pheromone	A formulation was sprayed up into the canopy using a ground spray apparatus
Sprayable Pheromone + Confirm/Lorsban	The same formation was sprayed up into the canopy, followed by either Confirm or Lorsban for subsequent codling moth control
Control	No pest control was used

**TABLE 2 - Walnut PMA 2001 *Trichogramma* Release Dates**

Grower	Total Acres	County	Release Dates
Deseret Farms	3.0	Butte	August 8, 14, 21, 28
Deseret Farms (D-10)	6.0	Yuba	August 6, 13, 20, 27
Chappe	2.5	San Joaquin	August 3, 10, 17, 24
Campos Brothers Farms	5.0	Fresno	August 4, 12, 18, 25

**TABLE 3 - Walnut PMA 2001 Aerial Pheromone Application Dates**

Grower	Total Acres	County	Release Dates
Deseret Farms	5.4	Butte	April 5

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**TABLE 4 - FACT SHEET on Mating Disruption in Walnuts to Control Codling Moth**

County	Isomate	Isomate + <i>Trich</i>	Isomate + Confirm	Sprayable Pheromone	Sprayable + Confirm	Confirm	Check	Grower Std	Aerial Isomate
Butte	0.00	0.20	0.00	0.40	0.20	0.00	2.80	0.40	
Yuba*	2.40	0.60	2.00	0.80	0.20	1.00	0.40	0.40	3.20
Fresno	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
San Joaquin	0.2	0.0	0.9	0.0	1.2	0.7	4.0		
Tehama	0.10	ND	0.00	0.00	0.00	0.00	0.40		
Average	0.54	0.20	0.58	0.24	0.32	0.34	1.52	0.27	
Std Dev	1.04	0.28	0.88	0.36	0.50	0.48	1.78	0.23	

\*Used Lorsban instead of Confirm

**TABLE 5 - Total Costs of All Treatments Compared to Grower Standard**

Reduced Risk Treatment	Cost per acre	Grower Standard (by County)	Cost per acre
Isomate	\$132	Butte	\$74
Isomate + <i>Trichogramma</i>	\$212	Yuba	\$157
Isomate + Confirm	\$170	Fresno	\$84
Sprayable pheromone	\$304	San Joaquin	\$169
Sprayable pheromone + Confirm	\$342	<b>AVERAGE COST</b>	<b>\$121</b>
Confirm	\$38		